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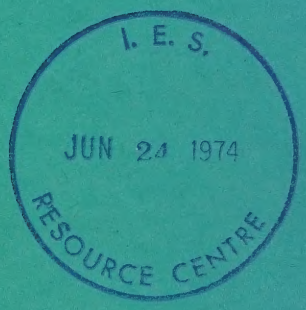
Maritime Fish Processing Plant Effluent Study



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January, 1974

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MARITIME FISH PROCESSING

PLANT EFFLUENT STUDY

by

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ABSTRACT

Fish processing plants located in Nova Scotia, Newfoundland and New Brunswick were studied to determine the waste characteristics and water usage in the groundfish filleting and sardine canning processes. From the analytical data, flow measurements and production figures, the effluent loadings in terms of pounds of BOD_5 and pounds of suspended solids per thousand pounds of roundfish and final product were determined. It was found that water usage was dependent on the size of the plant but effluent loadings varied depending on the type and quality of fish processed.

Key Words: BOD_5, characteristics, effluents, fish, fishmeal, fish processing, groundfish, Maritime provinces, production, sardines, suspended solids, wastewater, water usage.

RESUMÉ

Des études ont été faites dans des usines de traitement de poissons en Nouvelle-Ecosse, à Terre-Neuve et au Nouveau-Brunswick pour déterminer les caractéristiques des déchets et l'utilisation de l'eau dans les procédés de filetage des poissons de fond et de mise en conserve de la sardine. La charge des effluents en livres de DBO_5 et en livres de matières en suspension par mille livres de poissons de ronde et de produit fini a été déterminée d'après les données analytiques, les mesures de l'écoulement et les chiffres de production. L'étude a révélé que l'utilisation de l'eau variait en fonction de la grosseur de l'usine, mais que la charge des effluents variait selon le type et la qualité de poisson traité.

Mots clés: DBO_5, caractéristiques, effluents, poissons, farine de poisson, traitement du poisson, poissons de ronde, provinces Maritimes, production, sardines, matières en suspension, eaux usees, utilisation de l'eau.

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CONCLUSIONS

Based on a study of groundfish processing plants in the Atlantic Region with capacities ranging from 300,000 pounds of raw fish per day to 30,000 pounds of raw fish per day and of a sardine processing plant with a capacity of about 50,000 pounds of raw fish per day, the following conclusions can be drawn:

1. The effluent loading associated with the fresh fish flumewater varied from 1.2 to 2.8 pounds of BOD_5 per 1000 pounds of raw product and the suspended solids loading varied from 0.6 to 4.4 pounds per 1000 pounds of raw product from a groundfish processing plant.

2. The effluent loadings from offal flumewater varied from 7.9 to 19.0 pounds of BOD_5 per 1000 pounds of raw product and from 6.5 to 29.0 pounds of suspended solids per 1000 pounds of raw produce from groundfish processing plants.

3. Examination of the data obtained (Tables 5 and 6) indicates that variations in these effluent loadings cannot be attributed to variations in plant size. It should also be noted that the major water load occurs from the discharge of offal flumewater. The use of dry transportation of raw fish into and offal from a processing plant would therefore significantly reduce the effluent load.

4. In general, it was found that the sardine canning operation produces effluents which are considerably stronger in concentration than the effluents from a groundfish processing plant.

5. The total water usage figure for groundfish processing was determined to be about 5,000 Imp. gallons per 1000 pounds of raw fish and it was found that water use did not appear to vary materially with variations in plant size. The total water usage for sardine canning approached 4,500 Imp. gallons per 1000 pounds of raw fish.

6. The processing of offal into fishmeal results in the production of high strength wastes, specifically bloodwater, with a BOD_5 in excess of 120,000 mg/l and stickwater with a BOD_5 in excess of 100,000 mg/l. These waste products should not be discharged with other fishmeal plant wastes, but should be recovered and returned to the fishmeal production process.

7. Nitrification did not significantly affect the 5-day biological oxygen demand results of fish plant effluents.

SECTION 1

INTRODUCTION

This survey was undertaken to determine the waste characteristics of various effluents originating from the processing of groundfish and sardines. The study was carried out at plants in Nova Scotia, New Brunswick and Newfoundland during the summer of 1972.

The effluents from the plants studied were monitored for varying lengths of time and were analysed for BOD_5, COD, suspended solids, total and total volatile solids and pH. In order to determine the unit effluent load from each fish processing plant, flow rates for each effluent stream were determined and plant production information obtained from plant management.

A mobile laboratory, located as close as possible to the areas at which samples were taken, was used to analyse all samples. The necessity of supplying both electricity and freshwater to the laboratory often dictated the location of the trailer at each plant location.

Emphasis during the study was placed on the processing of Atlantic groundfish, primarily cod and flounder. Monitoring was also done at a sardine canning plant, and at fishmeal plants in cases where these reduction facilities were attached to the processing plant. Monitoring was also carried out at two whale processing plants. The fish and whale processing plants samples, together with the major species of fish processed, are given in Table 1.

TABLE I

PLANTS INVOLVED IN THE MARITIME FISH PROCESSING EFFLUENT STUDY (1972)

PLANT	TYPE
National Sea Products, High Liner Division, Lunenburg, Nova Scotia	Groundfish Filleting
Bonavista Cold Storage, Grand Bank, Newfoundland	Groundfish Filleting
Booth Fisheries Canadian Co. Ltd., Fortune, Newfoundland	Groundfish Filleting
Newfoundland Quick Freeze Ltd., South Dildo, Newfoundland	Groundfish Filleting
Fur Farmers Feed Cooperative, South Dildo, Newfoundland	Groundfish Filleting
Connors Bros. Ltd., Plant #2 Black's Harbour, New Brunswick	Sardine Canning
Karl Karlson Shipping Co., Blandford, Nova Scotia	Whale Processing
Arctic Fishery Products Ltd., South Dildo, Newfoundland	Whale Processing

SECTION 2

DATA COLLECTION

Samples from effluent streams at the aforementioned fish processing plants were analyzed for BOD_5, COD, SS, TS, TVS and pH. In many cases, all of the effluent lines could not be sampled due either to the large number of discharge points or the inaccessibility of the effluent streams. Whenever possible, composite samples were made up twice per day to represent the morning and afternoon effluent concentrations of that particular stream. These composite samples were made up of samples taken hourly, volumetrically proportional to the flow rate at that time.

All laboratory analyses were performed according to the techniques outlined in Standard Methods (1). To provide results which were as representative as possible, all samples were blended prior to analysis and, in order to minimize biological degradation, refrigerated until all testing had been completed.

In order to determine the actual BOD_5 and suspended solids loadings in terms of pounds per day, the flow rates of the sampled streams were estimated by either a "bucket and stopwatch" technique or a "floating chip and stopwatch" method. At one plant, all salt water used was metered, but the flow in individual streams had to be determined. It was decided to relate the effluent loading to plant production and thus production data, in terms of roundfish processed, as well as quantity of final product, were obtained for each sampling period from plant personnel.

SECTION 3

PROCESS DESCRIPTIONS

3.1 Fish Processing

The processes which characterized the plant studied during the survey are:

1. Groundfish filleting
2. Sardine canning
3. Fishmeal production

Five of the plants studied were involved in groundfish processing whereas only one sardine canning operation was studied. The main characteristics of groundfish filleting and sardine canning are shown in Figures 1 and 2. Of the five groundfish processing plants studied, three had reduction facilities for the production of fishmeal on site. The remaining fish processing plants trucked offal to nearby fishmeal plants.

In order that the differences in operation of these plants may be noted, each plant process will be described individually in more detail, with particular references to effluent discharge points.

3.1.1 Groundfish Filleting

3.1.1.1 Plant #1

This plant produced fillets from all types of groundfish including cod, haddock, halibut, redfish (ocean perch), catfish, flounder, yellowtail, sole and pollack. Some scallop processing is also carried out.

The fish, which have been eviscerated at sea, and unloaded from the trawlers by buckets or mechanical conveyors and stored on ice in 500 lb. cases prior to processing. The roundfish are then emptied into bins where the ice is washed away and the fish carried by a dry conveyor system to the cutting tables for filleting, trimming and skinning. Offal is flumed to the meal plant for further processing

Figure 1. Schematic Representation of Groundfish Filleting Process

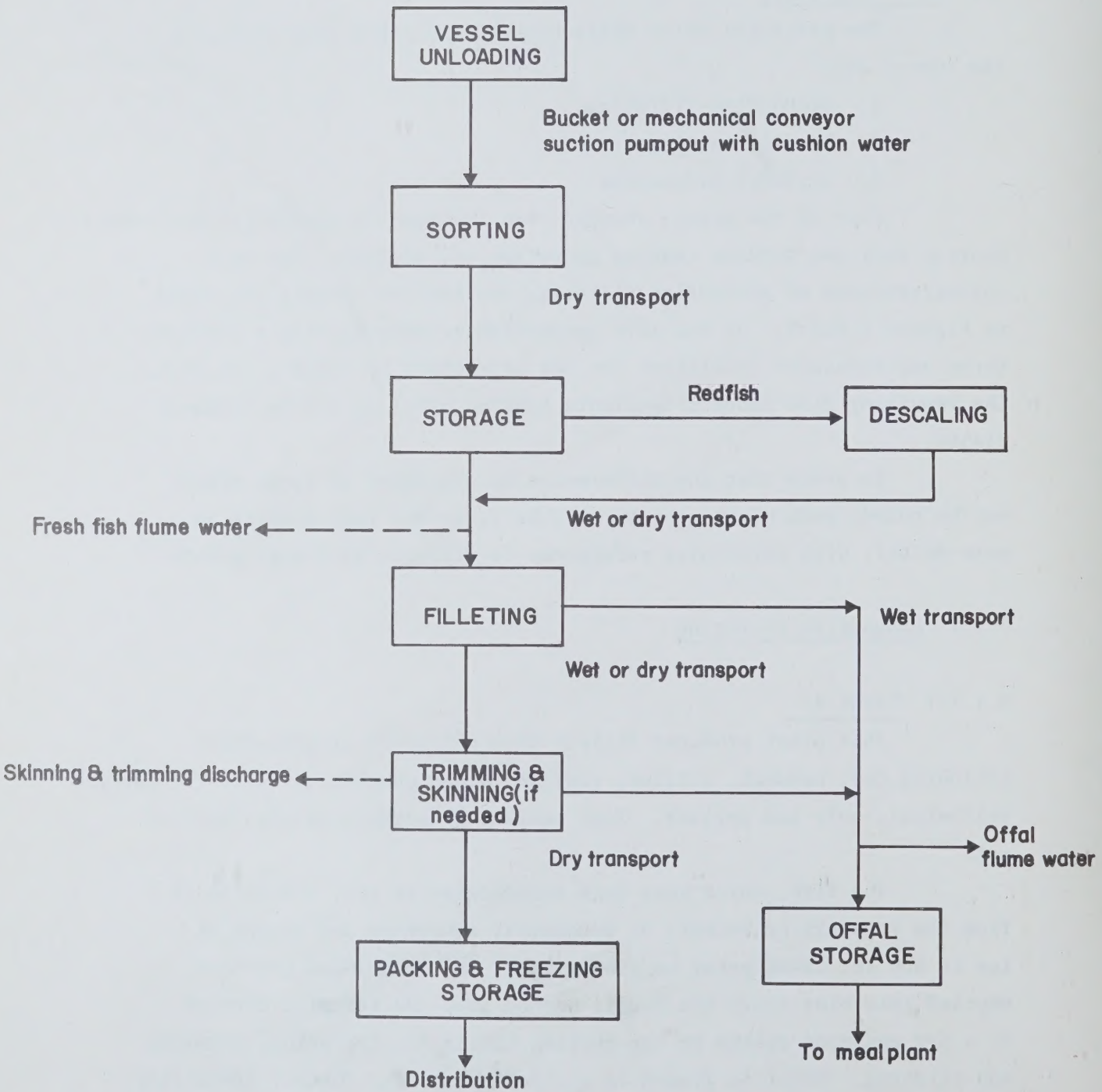
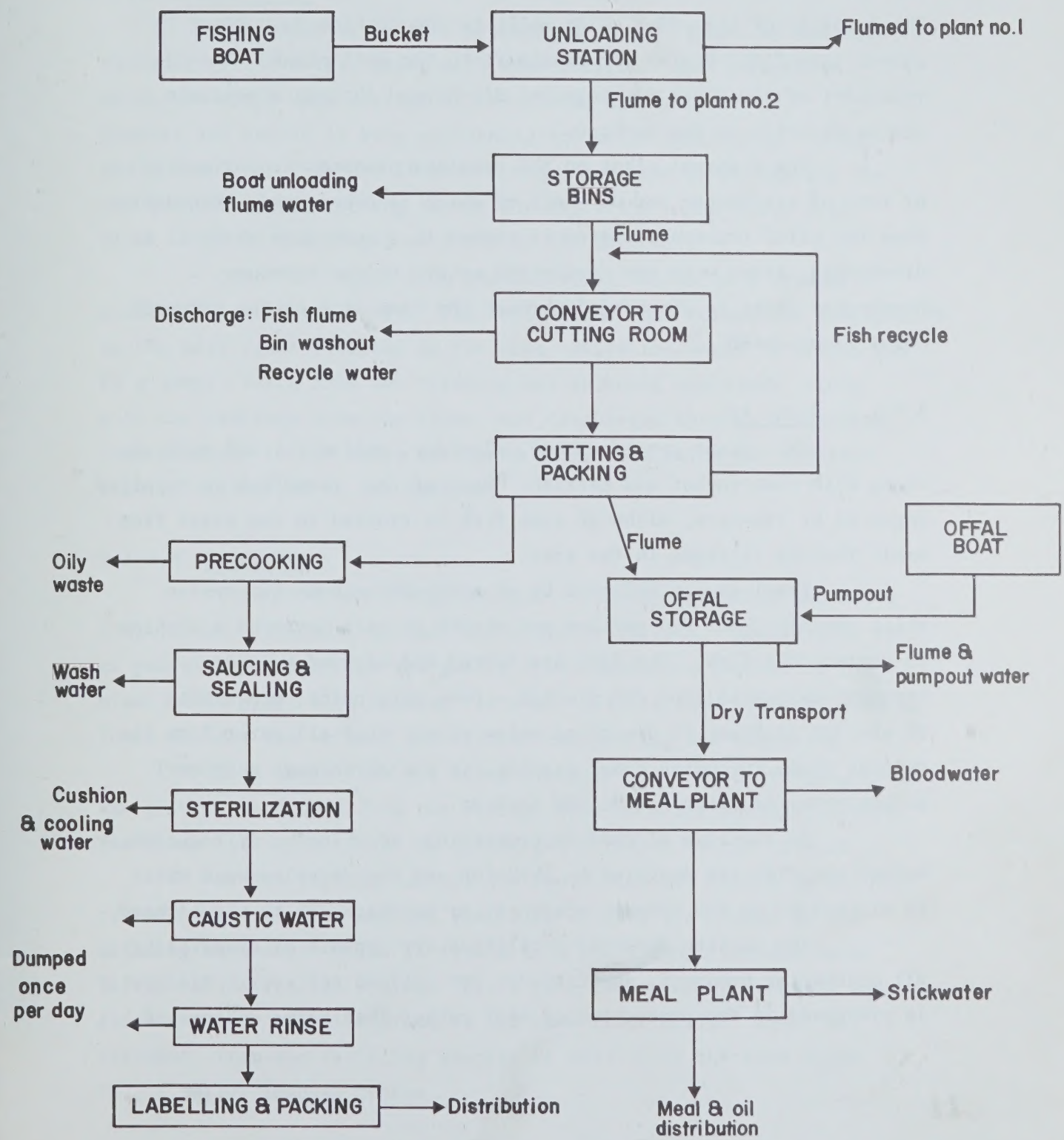


Figure 2. Schematic Representation of Sardine Canning Process



and the flume water discharged through 1/4" screens to the harbour. The majority of the offal which falls to the cutting room floor is washed into floor drains for transport to the meal plant. The remainder of the floor washings are discharged through a separate system directly to the harbour.

The fishmeal plant on the premises produces approximately 67 tons of stickwater per day, all of which is evaporated. Bloodwater from the offal transport system is washed to a sump from which it is discharged, along with the deodorized water, to the harbour. Evaporator water is discharged through the same line as the screened offal flume water.

3.1.1.2 Plant #2

This plant processes cod, flounder, yellowtail and redfish, along with some turbot and catfish. Most of the roundfish is supplied ungutted by trawlers, although some fish is trucked to the plant from small fishing villages in the area.

Trawlers are unloaded by an air-suction pump-out system which employs about 500 gallons per minute of salt water as a cushion to protect the fish. The fish are sorted and carried by a dry conveyor system to bins for storage. From this point, processing is similar to Plant #3 described below except that all water from the cutting room, including floor washing, is passed through a trommel screen prior to discharge to the harbour.

In the case of redfish processing, no skinning is required. Rather the fish are descaled by abrasion and the descaler wash water is discharged to the trommel screen prior to discharge to the harbour.

The on-site fishmeal facilities are capable of evaporating all stickwater produced, about 40,000,000 gallons per year. Bloodwater is processed in the production of meal rather than being discharged.

3.1.1.3 Plant #3

The majority of fish processing at this plant is cod and flounder (yellowtail), along with some catfish. The roundfish which are whole upon arrival at the plant, are unloaded by buckets and stored in bins containing ice until processing. From these bins, the fish are flumed to a dry conveyor which carries the raw product to the cutting tables for filleting. The fresh fish flume water is discharged directly to the harbour.

Offal is flumed from the filleting tables to a trommel screen (dewatering barrel). The solids from this screen are transported to the meal plant situated on the site, while the water is discharged to a sump. Waste from the trimming and skinning operation, along with the washings from the floor, are discharged through a separate line directly to the above mentioned sump, from which the combined flow is discharged to the harbour.

3.1.1.4 Plant #4

This is a smaller groundfish filleting operation producing cod, turbot, flounder, catfish and greysole fillets. However, as well as processing groundfish and gutted fish, which are trucked to the plant, this plant also obtains "skin-on" fillets from "feeder" plants. These fillets are trimmed and skinned for packing and marketing.

When whole fish are being processed in this operation, the raw product is flumed from the storage area to a dry conveyor system. The fresh fish flume water is discharged directly to the harbour.

At the cutting tables, the whole fish are flumed to the cutters for filleting and the resulting fillets are flumed to the skinning machines. Offal is flumed to a floor drain for discharge to the solids removal system. Waste from the skinning machines and floor washings are discharged to the same floor drain. Thus, all effluent from the filleting process is carried by the same flume to the solids removal system.

The offal removal system consists of a conveyor grid onto which the flume water discharges. Offal is carried on the grid to a conveyor for storage prior to shipment to an outside meal plant. Offal flume water discharges through the grid to the harbour.

3.1.1.5 Plant #5

This operation is basically a small "feeder" plant which supplies unskinned fillets of cod and flounder to plant #4 for final processing. The actual processing at this plant is similar to that in plant #4 with the exception that only filleting is carried out. All effluents from the cutting table are discharged through one flume. This flume conveys the effluent to the same offal removal system as is used by plant #4.

3.1.2 Sardine Canning

3.1.2.1 Plant #6

The processing of sardines is basically the same as for groundfish, except that the fish are deheaded and detailed rather than filleted. The plant surveyed was one of four in the same area which process sardine and juvenile herring into $3\frac{1}{4}$ oz. club sardine cans.

Whole fish are unloaded from the boat holds by buckets and flumed to storage bins where they are kept in a dilute brine solution prior to processing. A complete bin of fish, about 7,200 pounds is washed from the bin and flumed to a dry conveyor system when the supply of fish on the cutting tables is diminished. Any fish not processed in one pass of the cutting tables are flumed back to the storage area to be recycled directly to the cutting room along with the fresh fish from the storage bins. Offal from the cutting process is flumed to a conveyor grid and, following solids removal, the water is discharged to the harbour.

The cut sardines are placed in cans for pre-cooking, the addition of sauces, topping and sealing, sterilization, can washing and rinsing, and final packing.

The meal plant at the site processes offal from the cannery as well as offal from other plants in the area. Some whole mackerel is also processed. The offal and roundfish from outside sources are pumped out to the supply boats to trommel screens and the offal stored for processing. Pumpwater is discharged directly to the harbour, as is stickwater from the production of meal and fish oil.

The actual effluent lines sampled at each of the plants, with the type of samples taken, composite or grab, are listed in Table 2.

3.2 Whale Processing

In conjunction with the study of effluent characteristics of fish processing plants, the waste from two whale processing operations was also sampled to compare the relative strengths of discharges from the two types of operations. The whaling industry is very rigidly controlled with respect to season and limits, as well as wastage of raw product. At both plants, one of which was located in Nova Scotia and the other in Newfoundland, the season extended from April to December.

The operation of a whale processing plant is, in many ways, similar to that of a fish processing plant, the major differences being due to the size of the animal. The major species involved at both plants were finback whales, while some hump and sperm whales were processed along with smaller minke whales.

The actual processing involves winching the animal, which has been bled at sea following harpooning, onto a flat cutting area. Here the whale is butchered for meat which is exported for human consumption. The remainder of the whale, which is mainly fat and bones, is then cooked and centrifuged to remove the oil. One of the plants had a meal plant on the premises, the stickwater from which was evaporated, while the other discharged the solid residue from the cooking operation to the harbour.

TABLE 2

EFFLUENT STREAMS MONITORED

Plant Number	Type and Daily Capacity	Streams Sampled	Type of Sample
1	Groundfish 300,000# Roundfish	Offal Flume	Composite
		Floorwash Water	Composite
		Bloodwater	Composite
		Deodorizer Water	Grab
		Evaporator Water	Grab
2	Groundfish 200,000-350,000#	Fresh Fish Flume	Grab
		Total Cutting Effluent	Grab
		Pumpout Cushion Water	Grab
		Redfish Descaler Washwater	Grab
3	Groundfish 180,000# Roundfish	Fresh Fish Flume	Composite
		Total Cutting Effluent	Composite
		Stickwater	Grab
4	Groundfish 120,000# Roundfish	Fresh Fish Flume	Composite
		Total Cutting Effluent	Composite
5	Groundfish 30,000# Roundfish	Fresh Fish Flume	Composite
		Total Cutting Effluent	Composite
6	Sardine 50,000#	Fishboat Unloading Flume	Grab
		Fresh Fish Flume	Grab
		Offal Flume	Grab
		Mealboat Pumpout Water	Grab
		Stickwater	Grab
		Bloodwater	Grab
		Precooking Discharge	Grab
		Retort Cooling Water	Grab
		Can Wash Water	Grab
		Can Rinse Water	Grab

The major source of water contamination occurs during the initial butchering process. At this time, any blood, either concentrated or diluted by seawater during the bleeding process, is washed from the cutting area to the receiving waters. No estimate of the flow rate was possible due to the method of discharge. An attempt was made to obtain whale stickwater samples for comparison with stickwater obtained from fishmeal production. Unfortunately, at the only plant producing stickwater, the meal plant was inoperative at the time of sampling.

Grab samples of bloodwater were taken on several occasions at the Newfoundland station and on two occasions at the plant in Nova Scotia. Concentrated whale blood samples were also taken to estimate the degree of dilution of bloodwater prior to discharge.

SECTION 4

RESULTS

The purpose of the study was to determine the waste characteristics of the various effluent streams from fish and whale processing plants.

4.1 Waste Characteristics

Major water usage in the fish processing industry, excluding that used for ice making, deodorizers and evaporators, is for the transport of fish to the processing area, and the removal of offal from this area. Thus, in the case of flume water, the analytical results from the samples collected were incorporated with the flow rate and production data to determine the effluent loadings in terms of pounds of BOD_5 and suspended solids per 1,000 pounds of roundfish and final product. For the other streams monitored, e.g., stickwater and bloodwater, the actual effluent concentrations are reported, due to the difficulty in obtaining flow rates insufficient analytical data and the wide variations in the concentrations obtained.

The streams sampled varied somewhat from plant to plant due to slight differences in the processing techniques. Also, it was not always possible to obtain composite samples if two plants were being sampled simultaneously or if, as was the case at the sardine cannery, no cold storage facilities were available for preservation of the samples during the sampling period. In cases where only grab samples were taken attempts were made to obtain representative samples of the effluent streams for analysis. The objective was to determine the total BOD_5 and suspendes solids of the effluents from the processing area and from the transport of fish to this area.

The average waste concentrations and standard deviations for the flume water samples are given in Tables 3 and 4. Tables 5 and 6 give the effluent characteristics, based on production for fresh fish flumewater, where applicable, and for offal flumewater.

TABLE 3: EFFLUENT CONCENTRATIONS OF FRESH FISH FLUMEWATER

Plant No.	Plant Daily Production (Lbs. Roundfish)	Average and Standard Deviation of Concentrations (mg/l)					
		BOD_5	SS	COD	TS	TVS	pH
1	300,000	NA[a]	NA	NA	NA	NA	NA
2	250,000	308±167	527±334	826±457	35,194±2379	4,516±990	7.07±0.26
3	180,000	505±195	124±110	640±363	684±342	451±281	6.50±0.20
4	120,000	127±88	41±29	171±124	170±170	131±82	6.36±0.29
5	30,000	370±169	127±69	537±260	529±377	273±112	6.54±0.46
6	50,000[b]	260±138	553±332	952±567	36,688±16,055	4,103±1,843	6.99±0.33

a. This plant utilized a dry transport system to supply fish to the cutting tables.

b. Sardine Cannery.

TABLE 4: EFFLUENT CONCENTRATIONS OF OFFAL FLUMEWATER

Plant No.	Plant Daily Production (Lbs Roundfish)	Average and Standard Deviation of Concentrations (mg/l)					
		BOD_5	SS	COD	TS	TVS	pH
1	300,000	171[a]±110	360±241	--	33,442±2436	3,880±2,083	7.2±0.20
		279[b]±91	290±139	--	17,212±2754	2,221±446	6.9±0.19
2	250,000	287±138	500±275	720±375	33,730±2751	4,718±2095	7.07±0.31
3	180,000	540±129	184±118	672±107	551±174	393±107	6.47±0.43
4	120,000	584±228	424±417	882±469	1,085±869	768±871	6.33±0.29
5	30,000	348±194	113±79	400±248	450±247	271±142	6.46±0.31
6	50,000[c]	275±340	588±404	920±581	36,843±7,107	4,019±1,437	7.23±0.28

a. Offal flumewater

b. Floor washwater. This plant utilized two separate discharges for the effluent from the cutting room.

c. Sardine Cannery.

TABLE 5: WASTE CHARACTERISTICS OF FRESH FISH FLUMEWATER

Plant No.	Plant Daily Production (Lbs Roundfish)	Lb. BOD_5 per 1000 lb.		Lb. SS per 1000 lb.	
		Roundfish	Product	Roundfish	Product
1	300,000	NA[a]	NA	NA	NA
2	250,000	2.3	8.6	4.4	16.3
3	180,000	1.2	4.3	0.6	2.0
4	120,000	2.8	6.5	0.9	2.0
5	30,000	--[b]	4.9	--	1.7
6	50,000[c]	4.5	12.1	9.5	25.7

a. This plant utilized a dry transport system.

b. No roundfish processing data available.

c. Sardine Cannery. Total does not include the contribution of water used to transport fish from boats to storage bins.

TABLE 6: WASTE CHARACTERISTICS OF OFFAL FLUMEWATER

Plant No.	Plant Daily Capacity (Lbs. Roundfish)	Lb. BOD_5 per 1000 Lb.		Lb. SS per 1000 Lb.	
		Roundfish	Product	Roundfish	Product
1	300,000	7.9	18.5	22.5	51.8
2	250,000	15.7	57.8	29.6	110.
3	180,000	19.0	66.9	6.5	19.8
4	120,000	16.0	36.5	11.1	27.4
5	30,000	--[a]	10.0	--	2.9
6	50,000[b]	4.1	11.0	8.3	22.2

[a] No roundfish processing data available.

[b] Sardine Cannery.

In plants where offal flume water from the filleting process leaves the plant separately from washwater used for automatic skinning machine washdown and floor cleanup, the results from the flume water and washwater are combined to give a total poundage of BOD_5 and suspended solids resulting from the cutting process.

Water usage as related to production are given in Table 7. Offal flume water refers to all water, both salt and fresh, which is used to remove offal and skins from the cutting area. In the case of the sardine cannery (plant #6), the water used to transport fish from the boats to the storage bins is not included in Table 7, but will be considered separately as there is no similar water usage in the groundfish filleting process. The BOD_5 and suspended solids resulting from this water usage are also dealt with separately.

In some cases the total flow rates were not measured, but estimated from the data included in a report prepared by Montreal Engineering Company (2) for the Atlantic Development Board. In the case of plant #2, the total salt water flow was metered and the flume flow rates were estimated from this data.

The type of water used in fish processing operations varies from plant to plant. Plants #3, 4, and 5 all use fresh water exclusively. The remainder of the groundfish filleting plants use salt water for all fluming of whole fish and offal, and freshwater for the handling of the fillets, such as at the automatic skinning machines. Therefore, the effluent from the filleting room consists of combined fresh and salt water.

At the sardine cannery, salt water was used exclusively for the handling of the roundfish but fresh water was used in the retorts and washing operations. Salt water was also used for pump-out water during the unloading of offal and roundfish for meal production.

In Table 7, for plants which do not use fresh water exclusively, water usage data is given in terms of a combined salt and fresh water figure for offal fluming and total plant water usage. Total water usage results for the sardine cannery (plant #6) are separated into the fresh and salt water components.

TABLE 7: WATER USAGE

Plant No.	Plant Daily Capacity (Lb. Roundfish)	Gallons per 1000 lb.					
		Fresh Fish Roundfish	Flume Product	Offal Roundfish	Flume Product	Total Roundfish	Usage Product
1	300,000	NA[a]	NA	7.165	16,700	--	--
2	250,000[b]	916	3,070	3,730	20,500	5,780[c]	32,900
3	180,000	246	880	3,725	13,230	5,205[d]	18,500
4	120,000	1,965	4,090	2,110	4,390	4,700[e]	10,000
5	30,000	--	1,280	--	2,130	--	--
6	50,000	1,724	4,638	1,481	3,985	3,353[f]	9,021
						932[g]	2,507

[a] Dry transport system.

[b] Flume flow rates estimated from total water usage.

[c] Total salt water measured by meter.

[d] Total water usage estimated from flume water data.

[e] Total water usage estimated from flume water data.

[f] Total salt water usage.

[g] Total fresh water usage.

Table 8 indicates the fraction of fish recovered as final product. In the case of the groundfish filleting plants, only plant #1 processed eviscerated groundfish. Plant #5 produced unskinned fillets, and plant #4 handled skin-on fillets, the weight of which is included in the weight of final product, as well as in the weight of "roundfish" processed.

4.2 Miscellaneous Effluent Concentrations

The following streams were monitored during this study and are characterized by average BOD_5 and suspended solids concentrations as given below.

4.2.1 Fishmeal Plants

4.2.1.1 Groundfish Stickwater

Stickwater, from a fishmeal plant processing groundfish offal, at an average production rate of 306 gallons per hour, has the following characteristics:

	Characteristics (mg/l)	
	BOD_5	SS
Average	115,990	9,310
Maximum	277,000	21,200
Minimum	52,800	2,700

4.2.1.2 Herring Stickwater

Stickwater, from a fishmeal plant processing herring and sardine offal, along with some fresh mackerel, at the average production rate of 2,200 gallons per hour, has the following average characteristics:

TABLE 8

RATIO OF WEIGHT OF ROUNDFISH PROCESSED TO WEIGHT OF FINAL PRODUCT

Plant No.	Plant Daily Production (Lb. Roundfish)	Lb. Final Product Lb. Fish Processed
1	300,000	0.424
2	250,000	0.271
3	180,000	0.283
4	120,000	0.468
5	30,000[a]	--
6	50,000[b]	0.371

[a] No roundfish data available.

[b] Sardine processing.

	Characteristics (mg/l)	
	BOD_5	SS
Average	66,884	30,240
Maximum	152,000	107,500
Minimum	24,950	7,050

4.2.1.3 Groundfish Bloodwater

The flow rate of blood from the screw conveyor system providing groundfish offal to the meal facilities was not determined. The suspended solids level was also not determined due to the difficulty of filtering the samples. The BOD_5 values of the bloodwater are given below:

	BOD_5 (mg/l)
Average	128,900
Maximum	164,750
Minimum	88,500

4.2.1.4 Herring Bloodwater

The flow rate of blood was, again, impossible to determine. In some cases, the discharge was from whole mackerel, which was being processed for meal, rather than sardine offal. During offal processing the bloodwater discharge comprised of decomposed fish, which contribute to the high solids level in this effluent.

	Characteristic (mg/l)	
	BOD_5	SS
Average	78,531	15,230
Maximum	206,000	61,550
Minimum	19,500	1,432

4.2.1.5 Deodorizer and Evaporator Water

Grab samples were taken on two occasions from a meal plant processing groundfish offal. Due to the lack of adequate data, the actual suspended solids and BOD_5 results for the samples analysed are given below.

	Characteristic (mg/l)	
	BOD_5	SS
Deodorizer	21	105
	--	84
Evaporator	8	79
	13	89

4.2.2 Redfish Processing

4.2.2.1 Redfish Pumpout Cushion Water

During the unloading of redfish from a trawler, two grab samples of discharged cushion water were taken for analysis. Again, the actual results are given, due to the lack of data. The flow rate of cushioning water was estimated at 500 gpm.

	Characteristic (mg/l)	
Sample #	BOD_5	SS
1	343	884
2	1476	724

4.2.2.2 Redfish Descaler Washwater

Redfish are descaled, prior to processing, by abrasion in a large rotating drum which is continuously washed with water to remove scales. Several grab samples of this washwater were taken for analysis and the BOD_5 and suspended solids levels are given below. No flow rate was measurable for this effluent.

	Characteristic (mg/l)	
Sample #	BOD_5	SS
1	145	321
2	1585	1360
3	3720	2555

The first sample was taken during the final washing period when no fish were actually being processed.

4.2.3 Sardine Canning

4.2.3.1 Sardine Precooking Waste

Following the packing of deheaded and detailed sardines into cans, the product is precooked with steam. A small quantity of oily waste results and is dumped prior to the sealing of the cans. The volume of waste is only about 2-3 gallons per precooker tray. The following gives the average characteristics.

	Characteristic (mg/l)	
	BOD_5	SS
Average	96,460	114,460
Maximum	231,000	362,000
Minimum	30,750	36,100

4.2.3.2 Retort Cooling Water

Following the sterilization of the canned sardines, the retorts are filled with water at a rate of about 350 gallons per 200 cases of cans. This water serves the purpose of cooling the product, but small amounts of oil and solids are washed from the cans and discharged with the water. The following average concentrations were found.

	Characteristic (mg/l)	
	BOD_5	SS
Average	133	150
Maximum	322	379
Minimum	22	10

4.2.3.3 Sardine Can Washwater

Following the removal of the sterilized products from the retorts, they are passed through an alkali bath to remove any residual oil. This bath is dumped once per day representing a total effluent volume of approximately 1200 gallons per day. This bath was sampled as near to the time of discharge as possible to obtain the actual quality of the effluent. The following results were obtained.

	Characteristic (mg/l)	
	BOD_5	SS
Average	2143	1324
Maximum	3260	3865
Minimum	630	146

4.2.3.4 Sardine Can Rinsewater

After the alkali wash bath, the cans are rinsed in a bath containing fresh water. This vat is also dumped once per day and contains 1200 gallons. The following average concentrations were determined.

	Characteristic (mg/l)	
	BOD_5	SS
Average	312	197
Maximum	474	420
Minimum	180	63

4.2.3.5 Mealboat Pumpout Water

Offal from sardine plants, as well as some fresh mackerel is discharged from mealboats by a pumpout system which uses about 650 gallons per minute of salt water. The offal or roundfish is separated by trommel screens and the pumpout water returned to the harbour. During the pumping of offal, which is often somewhat decomposed, this pumpwater is more contaminated than in the unloading of mackerel. Total daily usage of pumpout water is estimated at 200,000 gallons. Average concentrations are as follows:

	Characteristic (mg/l)	
	BOD_5	SS
Average	34,298	14,340
Maximum	96,350	35,550
Minimum	750	1,008

4.2.3.6 Sardine Unloading Water

The fresh sardines are unloaded from fishing boats and flumed to the storage bins. This flume water is screened to remove the fish and is discharged to the harbour. The following characteristics were determined for this effluent stream.

	Characteristic (mg/l)	
	BOD_5	SS
Average	1,424	2,273
Maximum	2,430	9,120
Minimum	223	328

The waste characteristic based on production were also determined as follows.

Characteristic	Lbs/1000 lbs. roundfish
BOD_5	2.02
SS	3.23

The water usage was found to be 142 gallons per 1000 pounds of roundfish, all of which was salt water.

4.3 Whale Processing Bloodwater Characteristics

A sample of concentrated blood was obtained from both minke and fin whales. These results are given below:

	Characteristic (mg/l)	
	BOD_5	SS
Minke Whale	229,000	960
Fin Whale	163,000	3,175

During the bleeding process carried out at sea and the cutting process the blood is diluted considerably prior to its discharge. Samples of this diluted blood were taken. The results of the analyses are given below.

	Characteristic (mg/l)	
	BOD_5	SS
Average	17,051	2,481
Maximum	51,000	5,590
Minimum	2,170	796

4.4 Nitrification of Fish Processing Wastes

Since fish processing wastes have a relatively high protein content it is possible that nitrification could occur during analysis for BOD_5 prior to the five day completion of the test. To determine if nitrification is making a significant contribution to the biological oxygen demand obtained by the five-day test, a sample of offal flume water from a groundfish processing plant was incubated and the oxygen demand measured after various lengths of time. The results are given below in Table 9 and plotted in Figure 3. The test was discontinued after thirteen days.

TABLE 9: NITRIFICATION OF FISH PROCESSING WASTE

Time (Days)	Oxygen Demand (mg/l)
1	165
5	478
7	558
9	741
12	933
13	960

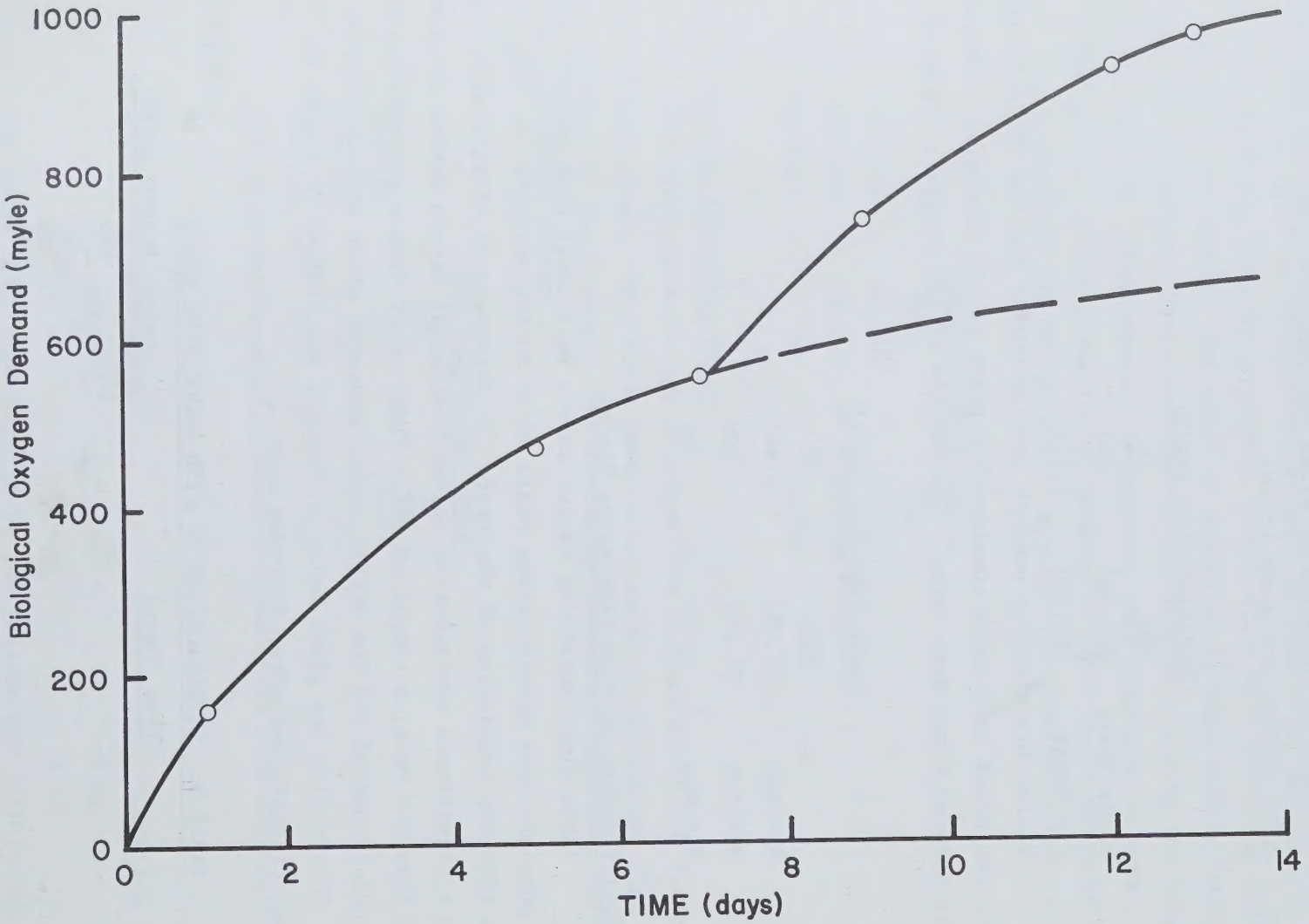


Figure 3. Nitrification of Fish Processing Waste

SECTION 5

DISCUSSION OF RESULTS

5.1 Analytical Results

There is considerable variation in the analytical results of all effluent streams sampled, especially BOD_5, COD and suspended solids, as shown in Tables 3 to 6 on pages 16-19. This is evidenced by the high values for standard deviation. These variations could be due to several factors.

Variations in fish quality will affect the effluent concentrations. Fish which have been stored for prolonged periods before processing become covered with a slime which is easily washed away by flume water. This slime affects the effluent parameters of fresh fish flume water, as well as offal flume water. The flesh of older fish is also softer than that of fresh fish and is therefore more easily torn by automatic skinning machines and requires more trimming. In addition, older fish are more easily broken up by the screw conveyors employed to transport offal to fish meal plants. Thus, the bloodwater composition is also affected by the storage time of the fish.

Sampling techniques are not always consistent, nor are processing procedures identical from plant to plant. As all processing is done by hand, except skinning, variations from area to area are inherent in the industry. Also, the concentration of the effluent stream is not constant. Thus, due to analytical inadequacies, sampling inconsistencies and effluent variations, some degree of variation is to be expected in the results.

Examination of effluent concentrations (tables 3 and 4, pages 16 & 17) shows a wide variation between plants. In the case of BOD_5 loadings due to fresh fish flume water from groundfish processing plants, (Table 5, page 18) there appears to be some consistency in the loadings as related to production. Suspended solids loadings from

this effluent show greater variation than the BOD_5 loadings. Both BOD_5 and suspended solids loadings from offal flume water also show considerable variation (Table 6, page 19).

Low offal flume water loadings from the smaller "feeder" plant (plant #5) was expected as no skinning or trimming was carried out. This is verified by the results as given in Table 6. Plant #2 showed a higher effluent loading for both offal flume water and fresh fish flume water due to the fact that a great deal of redfish was being processed. This is a very oily fish, and the high oil content of the flume water is indicated by higher suspended solids and BOD_5 loadings.

Higher effluent loadings from fresh fish flume water are obtained in sardine processing than in groundfish processing. This is due to blood which oozes from the herring during storage. Offal flume water is, however, lower in BOD_5 and suspended solids as the herring are merely deheaded and detailed and no skinning or trimming occurs, as in groundfish processing. BOD_5 effluent loadings from sardine offal flume water are comparable to offal flume water loadings from the small groundfish "feeder" plant (plant #5). However, a large number of scales are discharged in this effluent due to abrasion between the herring and this is indicated by higher suspended solids levels.

5.2 Water Usage

Flow rates measured did not show the degree of variation evident in the analytical results. This would seem to indicate that flow variations were due to inaccuracies in the measurements rather than actual plant variations. In many cases, measurements were difficult due to the volume of fish in the flumes, which caused blockage and backing-up of the flow.

The water usage figures related to production, given in Table 7, indicate considerable variation between plants. Water usage at smaller plants is, on a production basis, generally lower than at larger plants. This is due to shorter flumes supplying fish to the cutting tables, which are fewer in number than in a large plant. Plant #3 , however, used fresh fish flume water more efficiently than other plants, probably because of the more centralized storage bins. Water usage at the sardine cannery for fresh fish fluming was higher than at other plants due to the use of a recycle flume to return uncut fish to the processing area.

Offal flume water usage seemed to increase with the size of the plant. This seems to indicate a basic requirement for a minimum amount of water per pound of offal transported to prevent blockage of flumes.

In all cases, excessive amounts of water appeared to be used for floor washing. Inumerable hoses were left running and, in most cases, several inches of water depth were consistently present on the cutting room floors.

5.3 Whale Processing

Examination of the analytical results shows that actual concentration of the blood at the time of discharge varies greatly depending on the degree of dilution which occurred during the bleeding process, and the amount of water being used to wash the cutting area. Samples taken at one plant seemed to be more dilute. This is probably due to the fact that they were taken during the final stages of cutting. Actual discharge concentrations should have been similar at both plants as the method of processing was basically the same.

The BOD_5 and COD of concentrated whale blood is in the same range as fish bloodwater. However, the suspended solids level of whale blood is normally lower as whale blood is fresh, whereas, fish blood water results from the compression of often partially decomposed offal. The amount of blood discharged from the processing of whales is, however, much greater than the amount of bloodwater discharged

from a groundfish processing plant. This is indicated by the coloration of the receiving waters during the whale cutting process.

5.4 Nitrification of Fish Processing Waste

From the results of one test to determine the effect of nitrification on the degradation of fish wastes, it would appear that nitrification does not significantly affect the results obtained from the 5-day biological oxygen demand. It would appear that carbonaceous waste utilization continues for about seven days before the degradation of nitrogenous compounds becomes significant.

SECTION 6

CONCLUSIONS

Based on a study of groundfish processing plants in the Atlantic Region wich capacities ranging from 300,000 pounds of raw fish per day to 30,000 pounds of raw fish per day and of a sardine processing plant with a capacity of about 50,000 pounds of raw fish per day, the following conclusions can be drawn:

1. The effluent loading associated with the fresh fish flumewater varied from 1.2 to 2.8 pounds of BOD_5 per 1000 pounds of raw product and the suspended solids loading varied from 0.6 to 4.4 pounds per 1000 pounds of raw product from a groundfish processing plant.

2. The effluent loadings from offal flumewater varied from 7.9 to 19.0 pounds of BOD_5 per 1000 pounds of raw product and from 6.5 to 29.0 pounds of suspended solids per 1000 pounds of raw product from groundfish processing plants.

3. Examination of the data obtained (Tables 5 and 6) indicates that variations in these effluent loadings can not be attributed to variations in plant size. It should also be noted that the major waste load occurs from the discharge of offal flumewater. The use of dry transportation of raw fish into and offal from a processing plant would therefore significantly reduce the effluent load.

4. In general, it was found that the sardine canning operation produces effluents which are considerably stronger in concentration than the effluents from a groundfish processing plant.

5. The total water usage figure for groundfish processing was determined to be about 5,000 Imp. gallons per 1000 pounds of raw fish and it was found that water use did not appear to vary materially with variations in plant size. The total water usage for sardine canning approached 4,500 Imp. gallons per 1000 pounds of raw fish.

6. The processing of offal into fishmeal results in the production of high strength wastes specifically bloodwater, with a BOD_5 in excess of 120,000 mg/l and stickwater, with a BOD_5 in excess of 100,000 mg/l. These waste products should not be discharged with other fishmeal plant wastes, but should be recovered and returned to the fishmeal production process.

7. Nitrification did not significantly affect the 5-day biological oxygen demand results of fish plant effluents.

REFERENCES

1. A.P.H.A., W.P.C.F., Standard Methods for the Examination of Water and Waste Water, 13th Edition, 1970.
2. Montreal Engineering Company Limited, Maritime Provinces Water Resources Study - Stage I. Appendix III, Industrial Water Demands - Report Prepared for Atlantic Development Board, 1969.

APPENDIX I

RAW ANALYTICAL DATA

TABLE I-A: WHALE BLOODWATER ANALYTICAL DATA

Sample No.	Type of Sample	BOD_5	COD	SS	TS	TVS	pH
				(mg/l)			
1	Concentrated[1]	229,000	314,000	960	396,956	346,956	6.81
2	Concentrated[2]	163,000	184,000	3,175	179,260	101,964	6.33
3	Washing Effluent	5,320	--	1,360	35,120	7,536	6.40
4	Washing Effluent	2,170	--	1,240	32,276	5,372	6.73
5	Washing Effluent	10,845	17,120	1,900	41,324	9,060	5.65
6	Washing Effluent	6,250	12,100	796	37,800	9,060	6.91
7	Washing Effluent	51,000	63,700	3,040	71,396	31,124	6.62
8	Washing Effluent	18,030	25,500	3,590	45,620	14,032	7.44
9	Washing Effluent	23,850	38,500	5,590	57,872	19,616	6.66
10	Washing Effluent	11,380	16,950	2,200	35,012	10,648	6.80
11	Washing Effluent	24,620	35,400	2,610	55,748	19,752	7.14

1. Minke Whale

2. Fin Whale

TABLE I-B: FRESH FISH FLUMEWATER - GROUNDFISH PROCESSING
(Plant #2)

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	--	1,145	1,370	34,168	4,076	6.85
2	224	1,298	432	34,864	5,132	7.10
3	180	195	604	36,136	6,060	7.22
4	272	1,502	460	32,712	3,204	7.19
5	648	460	680	33,996	4,736	7.08
6	429	806	372	34,516	4,100	7.26
7	237	970	556	33,568	3,180	6.87
8	239	324	466	33,120	3,228	7.42
9	146	357	250	37,608	3,852	6.67
10	469	1,033	750	35,240	4,988	6.59
11	515	994	280	33,720	4,520	7.03
12	103	264	210	41,660	6,236	7.32
13	227	1,388	416	36,208	5,392	7.29
Average	308	826	527	35,194	4,516	7.07
Maximum	648	1,502	1,370	41,660	6,236	7.42
Minimum	103	195	210	32,712	3,180	6.59
Standard Deviation	167	457	334	2,379	990	0.26

(ii) Plant #3

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	829	--	165	828	360	6.65
2	664	--	70	700	344	6.55
3	322	--	73	396	200	6.10
4	392	--	--	448	176	6.43
5	678	--	64	1,112	508	6.53
6	406	--	108	300	240	6.30
7	333	424	80	384	384	--
8	735	1,287	370	944	716	6.62
9	718	854	348	1,168	1,012	6.84
10	269	250	58	304	196	6.34
11	398	422	55	428	304	6.46
12	284	312	13	520	276	--
13	395	612	87	728	604	6.45
14	651	960	116	1,320	992	6.74
Average	505	640	124	684	451	6.50
Maximum	829	1,287	370	1,320	1,021	6.84
Minimum	269	250	13	300	176	6.10
Standard Deviation	195	363	110	342	281	0.20

(iii) Plant #4

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	43	94	17	120	120	6.54
2	160	280	96	256	228	6.66
3	25	51	29	100	60	6.65
4	348	484	88	456	288	6.30
5	100	139	35	52	52	6.62
6	142	213	60	220	164	6.59
7	173	176	37	228	--	6.50
8	76	91	15	76	76	6.03
9	137	163	23	164	120	6.19
10	60	57	9	36	36	5.80
11	133	131	44	164	164	6.10
Average	127	171	41	170	131	6.36
Maximum	348	484	96	456	288	6.66
Minimum	25	51	9	36	36	5.80
Standard Deviation	88	124	29	170	82	0.29

(iv) Plant #5

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	106	183	56	204	192	6.43
2	582	815	200	792	392	6.36
3	450	668	128	660	356	7.06
4	462	795	220	740	368	6.84
5	254	342	65	400	128	5.80
6	365	418	94	376	204	6.73
Average	370	537	127	529	273	6.54
Maximum	582	815	220	792	392	7.06
Minimum	106	183	56	204	128	5.80
Standard Deviation	169	260	69	377	112	0.44

TABLE I-C: OFFAL FLUMEWATER - GROUNDFISH PROCESSING
(Plant #1)

(a) Flumewater

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	131	--	204	31,642	2,502	7.03
2	62	--	206	31,714	3,352	7.39
3	86	--	212	31,848	4,004	7.20
4	126	--	246	32,560	4,016	7.50
5	278	--	960	33.608	4,988	6.95
6	103	--	264	32,272	2,180	7.15
7	109	--	184	33,600	4,384	7.41
8	415	--	540	31,752	3,268	7.00
9	150	--	338	36,468	8,884	7.35
10	249	--	448	38,960	1,224	7.0
Average	171	--	360	33,442	3,880	7.2
Maximum	415	--	960	38,960	8,884	7.50
Minimum	62	--	184	31,642	1,224	6.95
Standard Deviation	110	--	241	2,436	2,083	0.20

(i) Plant #1

(b) Wastwater

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	178	--	140	17,820	2,664	6.81
2	--	--	230	14,490	1,628	7.10
3	178	--	264	15,724	1,976	6.90
4	256	--	170	18,132	1,828	6.68
5	364	--	372	21,884	2,604	6.90
6	389	--	576	19,252	2,072	6.65
7	359	--	232	13,180	2,104	7.18
8	226	--	336	17,212	2,892	7.00
Average	279	--	290	17,212	2,221	6.90
Maximum	389	--	576	21,884	2,892	7.18
Minimum	178	--	140	13,180	1,628	6.65
Standard Deviation	91	--	139	2,754	446	0.19

(ii) Plant #2

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	610	--	524	33,208	4,406	6.23
2	164	195	408	32,920	3,688	7.38
3	189	479	432	34,196	5,408	7.40
4	179	1,369	436	31,348	2,828	7.23
5	318	769	460	33,768	5,136	7.20
6	280	428	280	34,516	4,936	7.10
7	344	536	1,270	31,760	3,620	7.13
8	--	377	588	31,252	2,988	7.01
9	281	1,128	230	32,148	3,852	6.67
10	--	832	488	32,108	3,592	7.32
11	225	685	360	32,608	3,512	7.06
12	479	926	240	35,540	6,348	6.96
13	144	341	404	42,112	11,140	7.04
14	225	1,290	880	34,744	4,592	7.20
Average	287	720	500	33,730	4,718	7.07
Maximum	610	1,369	1,270	44,112	11,140	7.40
Minimum	144	195	230	31,252	2,828	6.23
Standard Deviation	138	375	275	2,751	2,095	0.31

(iii) Plant #3

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	--	--	308	480	460	6.13
2	584	--	140	488	268	6.28
3	418	--	127	404	224	6.32
4	606	--	167	452	260	6.10
5	739	--	140	712	380	6.25
6	678	724	92	428	384	6.23
7	--	672	52	492	464	6.00
8	271	500	108	392	328	--
9	460	684	260	464	384	6.50
10	682	876	544	1,020	624	7.20
11	599	789	176	556	432	6.29
12	540	676	131	516	428	6.58
13	549	579	196	572	356	--
14	459	612	168	460	352	6.75
15	435	611	144	824	548	7.45
Average	540	672	184	551	393	6.47
Maximum	739	876	544	1,020	624	7.45
Minimum	271	500	52	392	224	6.00
Standard Deviation	129	107	118	174	107	0.43

(iv) Plant #4

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	303	310	160	496	372	5.90
2	399	516	170	484	380	6.15
3	526	674	315	3,208	3,068	6.41
4	--	1,638	1,550	1,964	1,176	6.00
5	1,005	1,910	590	1,040	652	6.82
6	549	840	203	784	488	6.61
7	549	656	245	712	208	6.63
8	890	1,082	447	1,052	896	6.38
9	610	705	312	644	356	6.20
10	428	490	244	464	80	6.20
Average	584	882	424	1,085	768	6.33
Maximum	1,005	1,910	1,550	3,208	3,068	6.82
Minimum	303	310	160	464	80	5.90
Standard Deviation	228	469	417	869	871	0.29

(v) Plant #5

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	287	424	120	420	348	6.59
2	446	626	28	588	316	6.00
3	544	737	200	732	500	6.84
4	55	94	36	68	60	6.44
5	444	530	217	568	208	6.74
6	529	258	144	612	300	6.48
7	133	131	44	164	164	6.10
Average	348	400	113	450	271	6.46
Maximum	544	737	217	732	500	6.84
Minimum	55	94	28	68	60	6.00
Standard Deviation	194	248	79	247	142	0.31

TABLE I-D SARDINE CANNING EFFLUENT STREAMS

(i) Fish Unloading Flumewater (to storage Bins) - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	1,590	1,540	3,600	49,572	4,860	6.56
2	1,071	1,650	1,940	53,792	3,388	6.98
3	223	437	568	36,126	2,832	7.08
4	2,430	3,030	650	68,288	5,456	6.75
5	612	885	328	43,300	3,564	7.15
6	508	1,100	668	42,976	3,144	7.27
7	1,267	1,739	1,610	46,848	4,440	6.83
8	3,426	5,060	9,120	69,668	5,556	6.55
9	1,686	2,710	1,975	56,888	5,000	6.95
Average	1,425	2,017	2,273	51,940	4,249	6.90
Maximum	3,426	5,060	9,120	69,668	5,556	7.27
Minimum	223	437	328	36,126	2,832	6.55
Standard Deviation	1,013	1,406	2,765	11,435	1,036	0.25

(ii) Precooking Waste - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	--	46,570	6,880	77,292	29,064	6.20
2	--	36,100	8,860	75,648	29,164	6.10
3	--	82,800	32,280	91,244	39,864	6.10
4	116,300	169,100	58,450	127,568	56,640	6.05
5	30,750	47,400	3,565	66,696	29,772	6.89
6	231,000	362,000	34,500	151,200	105,580	6.05
7	37,500	49,900	9,000	69,476	31,164	6.01
8	66,750	121,800	41,480	116,580	69,820	6.20
Average	96,460	114,460	24,377	96,963	48,884	6.20
Maximum	231,000	362,000	58,450	151,200	105,580	6.89
Minimum	30,750	36,100	3,565	66,696	29,064	6.01
Standard Deviation	82,419	111,000	20,124	31,188	27,400	0.29

(iii) Fresh Fish Flume to Cutting Room Conveyor - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	491	752	738	39,244	5,852	6.48
2	310	369	1,184	69,692	3,316	6.78
3	495	654	1,395	36,684	3,864	6,74
4	246	451	226	39,664	3,216	7.21
5	138	1,760	486	37,460	3,220	6.90
6	140	1,290	281	35,340	3,612	7.70
7	322	1,690	425	34,260	2,496	7.05
8	126	316	464	38,648	3,456	7.39
9	201	1,359	240	34,488	5,844	6.90
10	218	1,005	580	35,572	4,040	6.67
11	83	1,662	920	38,192	4,080	7.06
12	505	460	454	43,732	3,736	7.00
13	435	1,612	504	41,408	10,304	6.48
14	147	378	494	34,800	3,240	7.30
15	142	1,600	290	34,668	3,856	--
16	156	292	478	33,856	2,708	7.03
17	271	534	240	35,644	2,912	7.12
Average	260	952	553	36,688	4,103	6.99
Maximum	505	1,760	1,395	69,692	10,304	7.70
Minimum	83	292	226	33,856	2,496	6.48
Standard Deviation	138	567	332	16,055	1,843	0.33

(iv) Offal Flumewater - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	207	676	1,442	36,684	5,080	6.98
2	144	1,120	220	63,904	3,192	7.16
3	210	289	525	35,684	3,864	6.74
4	52	82	68	38,560	7,444	7.52
5	103	352	310	34,912	3,302	7.29
6	75	255	273	33,712	2,892	7.80
7	144	1,464	285	35,308	4,460	7.09
8	143	882	298	33,760	1,484	7.51
9	138	1,474	695	33,880	2,908	7.00
10	165	897	296	33,644	3,256	7.30
11	150	1,434	545	34,084	3,400	7.31
12	--	1,610	1,252	35,288	4,340	7.05
13	612	1,176	860	35,600	4,388	6.78
14	277	545	650	37,016	6,348	7.37
15	1,455	2,185	1,290	35,628	5,328	7.50
16	243	409	682	34,084	2,816	7.38
17	285	778	298	34,584	3,820	7.12
Average	275	920	588	36,843	4,019	7.23
Maximum	1,455	2,185	1,442	63,904	7,444	7.80
Minimum	52	82	68	33,644	1,484	6.74
Standard Deviation	340	581	404	7,107	1,437	0.28

(v) Mealboat Pumpout Water - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
*1	--	1,152	2,400	34,532	3,644	6.70
2	72,900	86,300	34,260	76,720	43,372	6.42
3	96,350	123,000	35,550	89,304	57,532	6.70
4	21,930	44,800	10,075	54,368	17,104	6.40
5	36,400	69,100	19,050	64,620	22,408	6.48
6	34,275	45,990	12,250	56,860	19,784	6.00
7	14,450	17,800	7.660	40,736	7,720	6.74
8	23,200	47,700	26,100	54,160	18,252	7.39
*9	--	768	1,008	35,136	4,308	6.99
*10	750	2,840	4,200	38,596	4,356	7.07
11	23,750	47,800	11,020	55,860	24,564	--
12	18,980	23,200	8,500	45,600	13,444	6.51
Average	34,298	42,538	14,340	53,874	19,707	6.67
Maximum	96,350	123,000	35,550	89,304	57,532	7.39
Minimum	750	768	1,008	34,532	3,644	6.00
Standard Deviation	28,842	37,155	11,842	16,803	16,360	0.38

* These samples were taken during the unloading of whole mackerel for meal processing. The results are included in the averages since about 1/4 of the time whole fish rather than offal is being pumped and the average is therefore representative of the overall pumpwater concentrations.

(vi) Sardine Bloodwater - Plant #6

Sample No.	BOD_5	COD	*SS	TS	TVS	pH
			(mg/l)			
1	206,000	342,200	--	208,940	95,592	6.48
2	112,800	227,000	--	99,724	74,464	6.64
3	44,750	86,800	8,000	84,600	62,464	6.40
4	112,000	191,100	--	122,240	86,960	6.30
5	19,500	39,900	1,432	53,816	21,968	6.32
6	50,550	87,000	2,640	81,540	44,036	7.09
7	40,500	69,900	2,520	82,940	48,880	6.32
8	42,150	94,000	--	108,796	55,040	6.46
Average	78,531	142,240	3,648	105,325	60,800	6.50
Maximum	206,000	342,200	8,000	208,940	95,592	7.09
Minimum	19,500	39,900	1,432	53,816	21,968	6.30
Standard Deviation	61,785	99,969	--	46,621	23,448	0.26

* In many cases, it was impossible to filter the samples due to high solids concentrations.

(vii) Stickwater - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	152,000	285,000	107,500	136,824	92,592	6.56
2	24,200	48,100	7,050	45,304	24,416	6.98
3	60,600	74,550	15,750	74,136	35,404	6.58
4	49,100	52,100	13,450	61,200	30,548	6.68
5	76,950	90,750	25,500	87,728	59,184	6.58
6	69,250	96,200	17,650	92,288	57,268	7.36
7	57,750	73,950	34,700	123,840	83,920	6.38
8	45,224	83,500	20,300	82,880	37,600	6.30
Average	66,884	100,520	30,240	88,025	52,617	6.68
Maximum	152,000	285,000	107,500	136,824	92,592	7.36
Minimum	24,200	48,100	7,050	45,304	24,416	6.30
Standard Deviation	37,950	76,447	32,289	30,346	25,204	0.34

(viii) Retort Cooling Water - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/1)			
1	--	859	379	--	328	7.02
2	160	338	100	504	168	6.94
3	22	45	10	124	40	6.81
4	322	634	251	460	244	7.21
5	27	68	12	124	--	6.74
Average	133	389	150	303	195	6.94
Maximum	322	859	379	504	328	7.21
Minimum	22	45	10	124	40	6.74
Standard Deviation	141	194	124	180	122	0.18

(ix) Alkali Can Washwater - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	3,260	4,781	1,662	5,874	1,476	9.71
2	2,880	5,650	415	4,064	728	10.2
3	--	12,200	--	6,896	2,752	9.62
4	--	12,480	3,865	7,104	2,508	10.0
5	1,800	2,200	530	2,608	840	9.40
6	630	2,135	146	4,124	660	9.60
Average	2,143	6,591	1,324	5,112	1,494	9.75
Maximum	3,260	12,480	3,865	7,104	2,752	10.2
Minimum	630	2,135	146	2,608	660	9.40
Standard Deviation	1,183	4,675	1,534	1,793	930	0.29

(x) Can Rinse Water - Plant #6

Sample No.	BOD_5	COD	SS	TS	TVS	pH
			(mg/l)			
1	356	719	200	924	164	9.42
2	474	751	75	872	316	10.1
3	--	2,620	420	2,304	732	9.58
4	--	2,690	257	2,064	976	9.85
5	238	621	167	1,052	40	9.30
6	180	1,980	63	892	104	9.10
Average	312	1,564	197	1,351	389	9.56
Maximum	474	2,690	420	2,304	976	10.1
Minimum	180	621	63	872	40	9.10
Standard Deviation	130	981	132	652	380	0.37

Table I - E. Groundfish Processing Meal Plant

(i) Stickwater

Sample No.	BOD_5	COD	SS	TS	TVS	pH	Temp. (°C)
			(mg/l)				
1	277,000	--	14,000	79,220	74,676	6.35	75
2	177,500	--	8,450	91,004	64,000	6.80	81.5
3	97,230	--	2,740	86,340	59,780	6.83	58
4	52,800	--	4,400	36,704	26,800	6.79	41.5
5	79,760	--	2,050	78,412	48,444	6.35	54.5
6	92,230	--	3,800	87,104	61,376	7.00	56.5
7	155,000	148,000	7,350	79,944	44,586	6.65	53.5
8	104,800	148,000	2,700	94,112	74,440	7.09	74.5
9	87,500	121,000	5,850	32,776	25,072	6.42	25
10	118,500	118,700	11,325	86,768	23,536	6.86	57.5
11	119,800	120,300	10,650	100,600	33,932	6.76	59
12	93,500	124,300	20,200	103,292	78,968	7.15	57
13	81,850	106,000	16,400	72,304	59,548	7.00	61
14	98,150	95,900	8,600	95,504	64,372	6.71	57.5
15	104,250	132,600	21,200	107,464	80,120	7.10	59.5
Average	115,990	123,870	9,310	82,100	54,650	6.79	58.2
Maximum	277,000	148,000	21,200	107,464	80,120	7.15	81.5
Minimum	52,800	95,900	2,050	32,776	23,536	6.35	25.0
Standard Deviation	53,810	17,285	6,263	21,579	19,817	0.53	--

(ii) Bloodwater

Sample No.	BOD_5	COD	*SS	TS	TVS	pH
			(mg/l)			
1	161,000	--	--	96,820	73,764	5.45
2	164,750	---	--	101,720	80,860	6.40
3	124,500	--	--	80,900	61,596	6.42
4	105,750	--	--	113,532	79,568	6.59
5	88,500	--	--	108,204	86,180	6.83
Average	128,900		--	100,255	76,394	6.34
Maximum	164,750		--	113,532	86,180	6.83
Minimum	88,500		--	80,900	61,596	5.45

* It was impossible to filter the samples due to high solids concentrations and high viscosity.

APPENDIX II

PRODUCTION DATA
AND
FLOW RATE MEASUREMENTS

Plant Size: 300,000# Roundfish per day

Plant #1

Flow Rate (Imp. GPH)		Production (Lb/day)	
Offal Flume	Washwater	Roundfish	Fillets
56,450	--	77,195	33,786
74,215	2,512	148,255	60,897
64,300	2,746	158,825	69,292[1]
75,300	1,770	252,900	94,916
65,690	2,100	239,180	103,970
55,130	2,312	255,300	121,455[2]
68,740	1,659	166,465	74,586

[1] 9,225# scallops processed but not included in figures.

[2] 10,695# scallops processed but not included in figures.

Plant Size: 250,000# Roundfish per day

Plant #2

Total Daily Salt Water (Imp. GPD)	Production (Lb/day) Roundfish	Fillets
2,224,000	176,544	60,000
2,310,000	134,157	37,987
1,433,000	--	--
900,200	251,161	48,564
2,487,200	--	63,080
1,377,500	231,605	--
1,848,900	244,410	65,989
1,849,900	202,288	59,495
1,940,000	--	64,475
1,864,700	215,000	64,812
1,669,000	142,900	38,685
224,500	--	--
--	230,759	59,099
--	241,867	60,346
--	246,310	60,394

Plant Size: 180,000# Roundfish per day

Plant #3

Flow Rates (Imp. GPH)				Production (Lb/day)	
Fresh Fish Flume	Offal Flume	Wash Water	Stick-Water	Roundfish	Fillets
4,500	26,500	27,000	165	205,594	55,515
--	26,500	26,000	330	172,946	48,555
--	17,950	25,000	238	175,316	46,132
4,500	31,000	26,000	101	172,096	49,590
--	24,000	19,450	99	171,756	48,941
--	--	--	--	167,713	46,429
4,100	--	--	--	142,524	39,638
--	--	--	379	147,267	44,014
--	--	--	--	84,685	24,827
--	--	--	--	157,194	44,223
4,300	--	--	555	160,720	43,147
--	--	--	--	139,874	42,692

Plant Size: 120,000# Roundfish per day

Plant #4

Flow Rates (Imp. GPH)		Production (Lb/day)	
Fresh Fish Flume	Offal Flume	Roundfish	Fillets
5,950	5,250	75,355	23,720
6,397	7,224	118,553	27,375
5,975	6,800	122,175	37,383
8,550	7,280	90,694	30,971
5,323	6,712	67,662	40,069
5,700	6,250	28,163	21,965
7,400	7,150	40,391	9,554
--	--	30,744	27,558
--	--	18,185	6,276
--	--	25,765	2,534
--	--	63,787	22,323

Plant Size: 30,000# Roundfish per day

Plant #5

Flow Rates (Imp. GPH)		Production (Lb/day)
Fresh Fish Flume	Offal Flume	Fillets
1,080	1,700	576
1,100	1,420	2,144
865	1,140	3,005
700	1,440	7,789
1,110	1,340	6,662
1,050	2,060	4,519
--	--	3,203
--	--	1,757
--	--	636

Sardine Cannery - Plant #6

Flow Rates (Imp. GPH)					Production (Lb/day)	
Boat Unload Flume	Fresh Fish Flume	Offal Flume	Mealboat Pumpwater	Stick-Water	Roundfish	Fillets
--	6,570	7,000	28,200	--	37,615	13,860
5,775	5,270	8,500	25,920	--	33,405	11,940
5,400	8,180	7,900	33,000	--	43,340	16,480
--	6,620	8,100	--	2,170	50,840	19,940
5,775	8,240	8,500	50,000	1,506	49,600	17,700
5,630	7,390	8,100	--	1,890	52,080	19,180
--	6,340	8,070	43,400	2,700	53,320	20,280
8,065	8,660	7,200	37,000	2,940	50,840	20,420
--	6,100	6,725	--	1,980	59,520	20,080